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Details of Highway Bridges

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DETAILS
OF
HIGHWAY BRIDGES

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BY
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*
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FOR
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This is to certify that the thesis prepared under the
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JOHN HENRY FROST

entitled DETAILS OF HIGHWAY BRIDGES

is approved by me as fulfilling this part of the requirements for
the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

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DETAILS OF HIGHWAY BRIDGES

INTRODUCTION

"The details of highway bridges," says Johnson in his Modern Framed Structures, "should be designed with the same care and more attention should be paid to the non-eccentric connection of the several members meeting at a joint, than would be given to the design of railway bridge details. The members of the truss are smaller and the margin of safety, due to the use of higher unit stresses, is less, so that the secondary stresses caused by the eccentric connections have very destructive effects. Thus it is seen that the designing of the principal details is even more important than the determination of the sections and stresses, since the life of the structure depends largely upon these details."

Although the importance of the details for highway bridges has long been recognized, very few discussions have ever been written upon the comparative merits or defects of the various details used by the different bridge manufacturers. Even then, only the principal details were discussed, and the minor details which are continually causing trouble and expense, were almost totally ignored.

It is the purpose of the author in this thesis, to investigate the relative merits and defects of the main members and of the details of numerous highway bridges shown on the detail plans to which he has had access. In this investigation, the order of presentation is that of discussing the member first with regard to its section and general position in the bridge, and second, with

regard to its details. Shop drawings of over sixty highway bridges, built by fifteen representative companies of the United States, were investigated. These bridges were mostly Pratt-truss, pin-connected spans varying from 70 to 160 feet in length. Several parabolic-truss spans having lengths of 250 to 350 feet, and some small riveted pony-truss spans were also investigated. Access was also had to the leading engineering papers and magazines.

Where necessary , the author has drawn sketches of the details discussed, but no especial effort was made to make these sketches to scale, as their purpose is only to make the discussions more clear and comprehensive.

END POST AND UPPER CHORD.

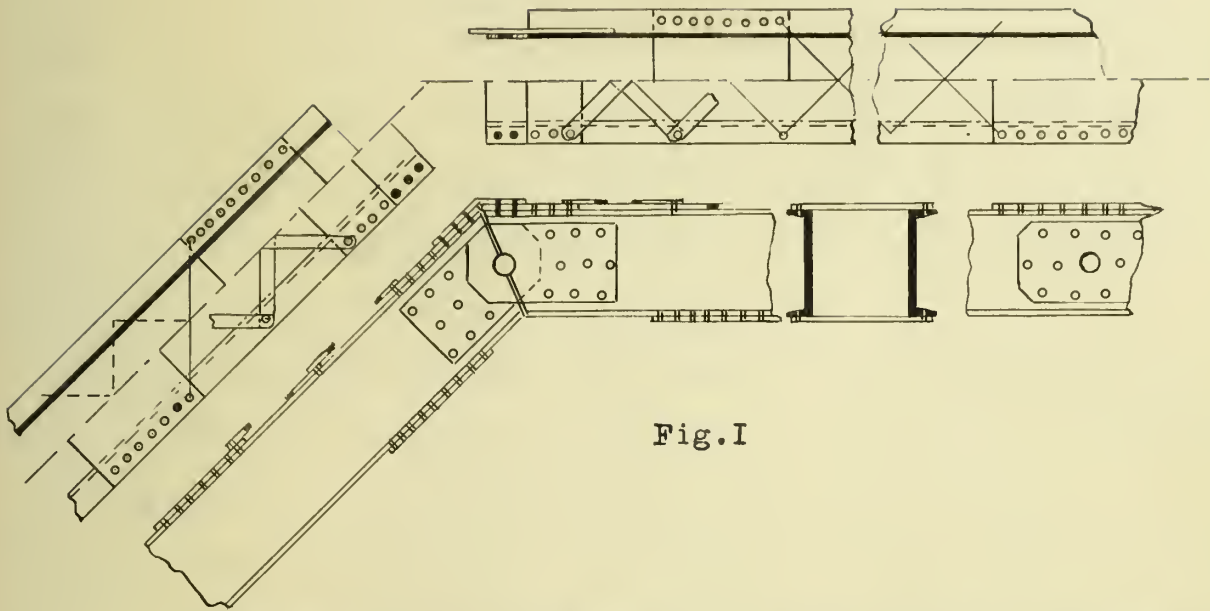


Fig. I

It may be first stated that in most of the bridges investigated the end posts and upper chords were of the same cross section through out. Although this necessitates excess area in some members, it is desirable because it simplifies such details as the rivet spacing, the lacing, the splicing; and because it reduces the templet and shop work. The members are designed with equal moments of inertia in the horizontal and vertical planes in order that the section may be economical.

An investigation of the American, Massillion, Indiana, Chicago, and Joliet Bridge Companies' standards for ordinary highway bridges of 80-to 150-foot spans, shows the universal use of two channels with the cover plate above and lacing below, or lacing both above and below, no built up chord sections being used.

The use of the cover plate is advantageous because

it stiffens the member, and is capable of taking considerable stress. The chief disadvantage of the cover plate is that it causes stresses due to the eccentric bearing of the pins. This eccentricity may be remedied by using flats on the bottom of the channels or by placing the pin off the central axis. This brings in the necessity of deepening the chord members as the latter are designed in depth to just give clearance between the eye-bar head and the cover plate. These difficulties in designing cause the cover plate to be avoided when possible.

The lattice-bars of the chord members investigated were inclined at the angles of 60 or 45 degrees to the longitudinal axis of the member, for single and double lacing respectively. In all cases noted, where a top cover plate was used, single lacing inclined at 45 degrees was used. This is permissible because the cover plate aids greatly in stiffening the member. Where double lacing was used, the bars were riveted at their intersection. Such practice is to be recommended as it stiffens both the bars and the laced member. As it is practically impossible to rationally design the size of the lattice-bars, these are usually assumed according to some specifications which are determined by practice and experience (see Johnson's Framed Structures, p. 527).

The ends of all laced members are stiffened by batten plates as shown in Fig. 1. Most of these plates were not in accordance with Cooper's Specifications as their length was only about one-half of their width instead of being one and one-half times the least width of the chord member. It is necessary that the plates should be at least $3/8$ of an inch thick in order to prevent buckling. Batten plates should be placed as near the end of the mem-

bers as possible so that they may keep the back-to-back distance constant and protect the pin connection from the weather .

The channels of the end post and upper chords are reinforced by pin plates at each pin connection, so that the allowable bearing on the pin shall not be exceeded. The pin plates are designed to take their portion of the total stress and are made long enough to allow the number of rivets required . In order that the pin plate may be an aid in stiffening the member, the longest pin plate is made to extend about six inches beyond the batten plate.

In large highway bridges the area required for the end

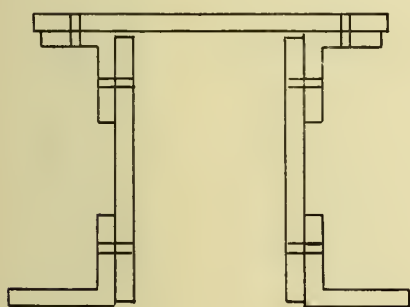


Fig. 2

post and upper chords can not be obtained by using channels, and therefore a section consisting of four angles and two side plates is used. This section may be laced above and below or a cover plate may be used. Fig. 2 shows the section in the Homestead and Pittsburgh bridge at Homestead, Pennsylvania.

The cover plate was used and the lower angles were made larger to remedy the

eccentricity. This detail is very good and should be used if the required area is great enough to allow it.

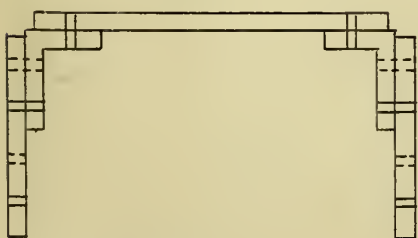


Fig. 3

Fig. 3 shows a peculiar cross-section of upper chord for a small span pony truss. It is very evident that this member could not be used in a pin-connected truss. It is further desirable

that rivet connections be used in order to stiffen this member as its moment of inertia about its horizontal axis is small. The moment of inertia about the vertical axis is made large because no transverse bracing is used.

INTERMEDIATE POSTS.

The cross section of intermediate post for the ordinary highway bridge consists of two channels connected with lacing as shown in Fig. 4. Where the required area can not be obtained by the use of channels, as in a very long bridge, posts are used con-

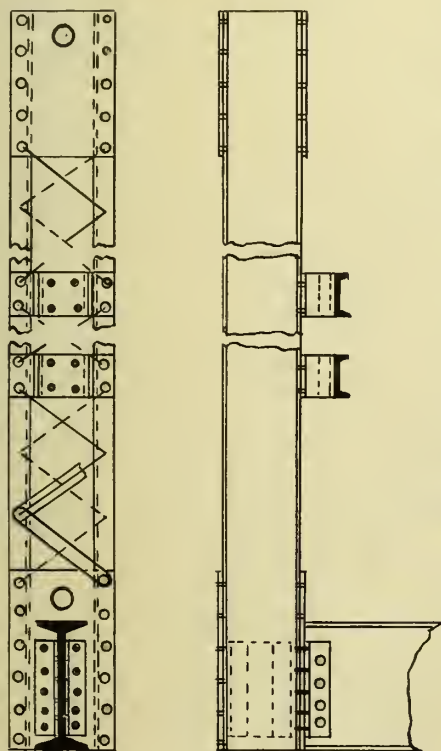


Fig. 4

sisting of four angles laced on all sides or connected with side plates and laced on two sides. This latter section is avoided when possible because of its increased cost of construction. The section of four angles, laced on all sides, is objectionable because of the difficulty of constructing a diaphragm which would equally transfer the stresses of the lateral struts and floor beams to all four angles.

Single eye-beams were once used for the intermediate post but were found defective. It is never good practice to use the eye-beam for a post because of the great variation in stiffness of its two principal rectangular planes and also because of the difficulty in making neat details for the connections.

In all cases noted, where laced channels were used ,

the flanges were turned out . Theoretically, it is more economical, so far as the area of the section is concerned, to turn the flanges in, for the moment of inertia is then greater; but, on the other hand, the difficulty of riveting in a confined place greatly offsets this advantage.

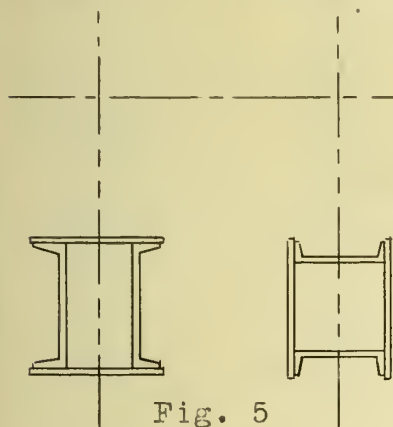


Fig. 5

Of the bridges investigated, some of the channels of the intermediate posts were placed with their web perpendicular to the roadway and some parallel to it. The placing of the webs perpendicular is advantageous, principally because the stress due to the floor beam is transferred equally to both channels.

It affords an easy and simple connection of the hub guard and also the opportunity of making well packed joints without the trouble of cutting off flanges as is sometimes done with the other form. Its chief disadvantage is that it has a fixed moment of inertia about the axis perpendicular to the web of the channels which permits no increase of stiffness about this axis where it is most needed. The placing of the web parallel to the roadway does away with the disadvantage just mentioned as the channels can be placed far enough apart to obtain the required stiffness . It also has the advantage that the web of the channel may give the required bearing on the pin and a pin plate will not be needed. The chief disadvantage of this form is that the floor beam stress is unequally divided between the two channels even when a good diaphragm is used. Also in most cases where this form is used the flanges are cut off in order to pack the joints well. Experi-

ments made by E.J. Ward of the Chicago and Alton Railroad, prove that the cutting away of the flanges reduces the strength of the post ten per cent (see The Designing of Ordinary Highway Bridges by Waddell, p. 59).

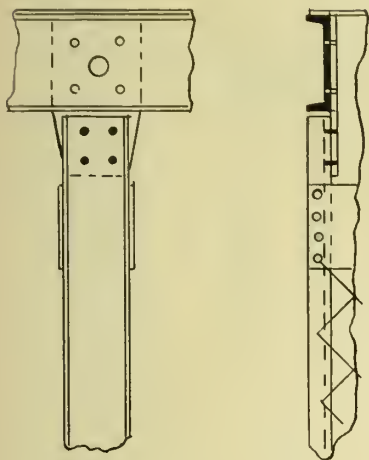


Fig. 6

The connection of the post to the top chord as shown in Fig. 6 was used in some of the Massillon and Joliet Bridge Companies' bridges. Many others similar to it, in that the pin plates were riveted to the chord member, were also noticed. The chief objection to this detail is that the deflection of the truss would cause flexural stresses in the members and increased shear on some of the rivets. These secondary stresses

have received much consideration only in the last few years and allowance is now generally made for them. It is also objectionable to have a light protruding plate riveted to a heavy member because of its liability of being bent and distorted during transportation.

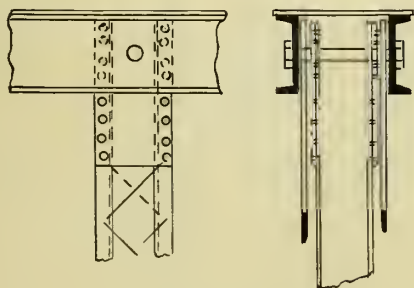


Fig. 7

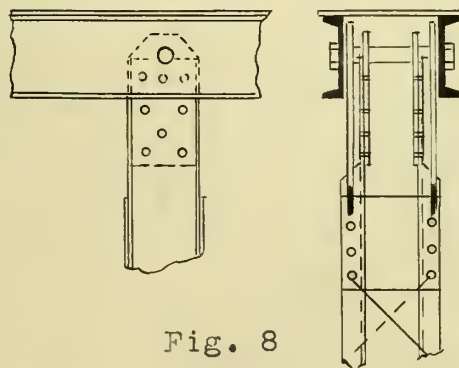


Fig. 8

The two connections shown in Fig. 7 and Fig. 8 eliminate the possibility of secondary stresses and are also simple in detail. They require no field riveting and facilitate erection.

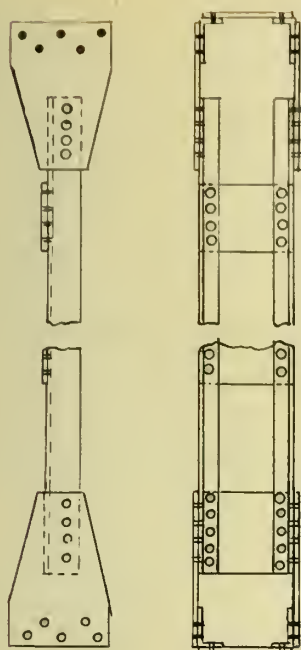


Fig. 9

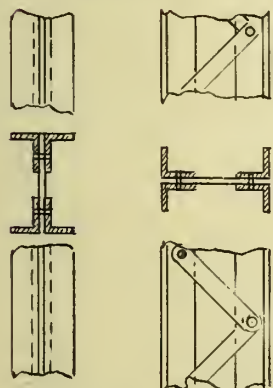


Fig. 10

Fig. 9 shows the construction that was found among the forms of end posts for small, riveted, pony-truss spans. It consists of two angles connected by three batten plates. It would be decidedly objectionable, if the posts were not very short and did not have riveted joints to aid in stiffening them. It has the largest moment of inertia about the axis where bending is most liable, and as it takes but very little force to keep a short post from bending, the hub guards prevent this about the other axis.

Another small truss of this type had four angles laced together for an intermediate post, as shown in Fig. 10. This post is better and more efficient than the above but it could only be used, like the above, for a short post in a small, riveted, pony-truss span.

HIP VERTICALS

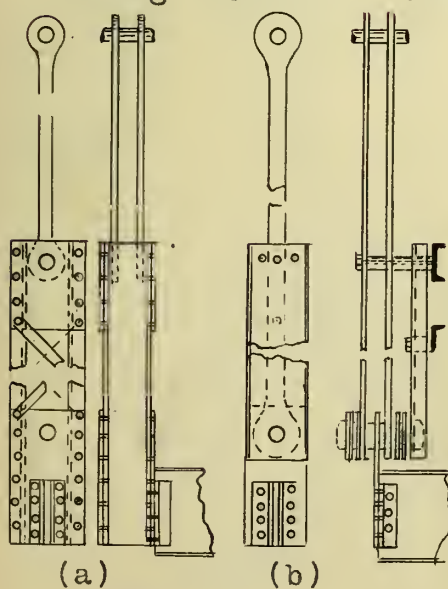


Fig. 11

Sketches (a) and (b) of Fig. 11 show the two forms of hip verticals that are most generally used. One consists of two loop or eye-bars extending from pin to pin and the other consists of a short sub-post which is connected to the top pin by two eye-bars.

The latter form is preferable because it affords a stiffer connection for the floor beam than does the former and it does not require a special construction for the support of the hub guards and the side walk. The latter also, on account of the manner in which the floor beam is connected, divides the stress more evenly in the eye-bars than would be the case in the first form, where the stirrup or hanger plate would tend to cause eccentric loading on the pin.

With riveted trusses the hip vertical of necessity, is a stiff member. The hip vertical of one small, riveted, pony-truss span was of the same section as the intermediate post. This section is not ordinarily economical as in such cases the efficiency would be too great, but in the case cited the smallest angles allowable were used throughout.

FLOOR BEAM CONNECTIONS

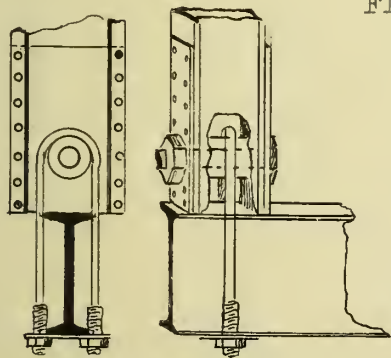


Fig. 12

The stirrup support for floor beams shown in Fig. 12 is defective in the following respects: The stirrup is made of a round steel bar as one of square cross-section would be difficult to upset. This steel rod has very little surface contact on the pin and would therefore have excess bearing on the pin. The floor beam is supposed to be stiffly attached to the post by being firmly screwed up to the bottom of the post, as shown in the illustration. Thus any movement of the floor beam jars on the ends of the channels and pin plates, causing a loosening of the pin plates by its lever ac-

tion. Also when the floor beam is loaded, the stirrup elongates and the contact of the floor beam with the bottom of the post is lost, taking with it the rigidity when it is most needed. It may be also noted that holes have to be drilled in the floor beams for the stirrups, necessitating a special machine and causing considerable expense.

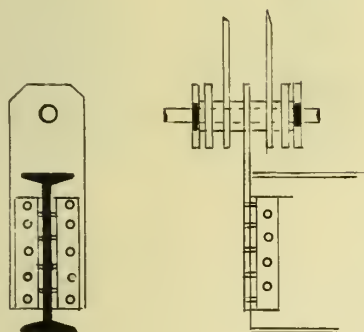


Fig. 13

Fig. 13 shows a method of attaching the floor beam to a hip vertical that consists of eye-bars. It is readily seen that the hanger plate is only a modified form of the stirrup and the latter's faults naturally accompany it, except that the plate has a better bearing surface and is cheaper as its construction is more simple. Although it has no nuts

to work loose it can not even pretend to have any stiffness. The fact that it accompanies a bad form of hip vertical will eliminate further discussion of this detail.

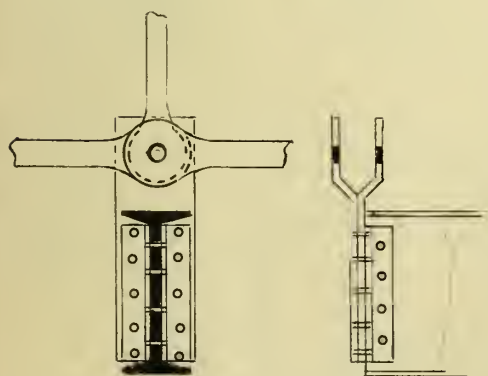


Fig. 14

It is apparent at once, that Fig. 14 shows another type of floor beam hanger similar to the preceding. In addition to the objections to the latter, the use of bent plates is also an objection because of the shop expense incurred in bending them. This detail has a little better bearing surface on the pin than either of the two details mentioned above and would not be as liable to eccentric loading, but it cannot pretend to afford

a stiff joint.

This connection shown in Fig. 15, which has a floor beam riveted to the inner side of the post, is a step in advance, as it is at least an attempt to make a rigid connection to the post.

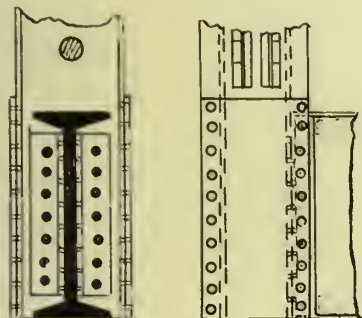


Fig. 15

However, in this detail, the floor beam is directly connected to one channel and the two batten plates do not transfer half the stress to the other channel. This produces eccentric stresses in the post and also eccentric loading on the pin.

The floor beam connection shown in Fig. 16, is similar to the preceding, except that the floor beam is connected to the inside pin plate, which transmit the stress to both channels of the post.

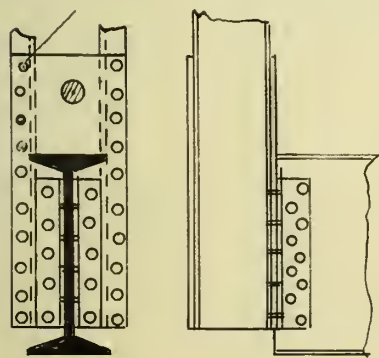


Fig. 16

The webs of the channels have to act as the transmitters of the stress to the outside of the post, and are therefore under a torsional stress. Also the bearing of the pin plate would be unequal and would cause eccentric bearing on the pin.

The floor beam connection of Fig. 17 shows a method of obtaining a uniform stress in the post by inserting a diaphragm of four angles and a plate.

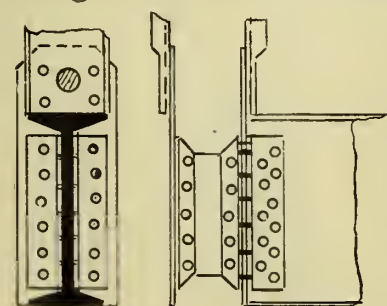
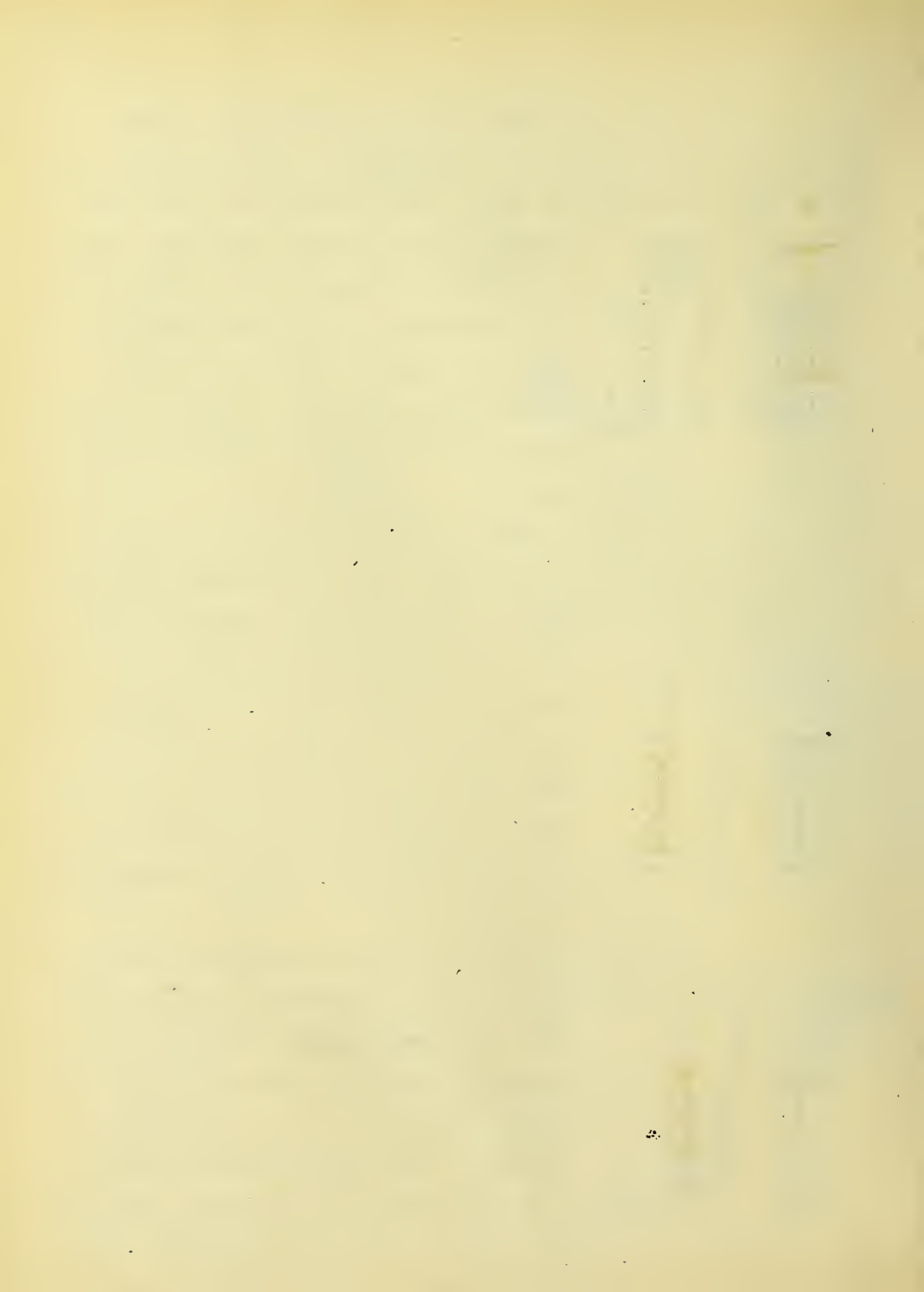


Fig. 17

Although this purpose is fairly well accomplished, there is a defect in the connection to the post. The hanger plates are riveted to the post but not strongly enough to make a good, permanent and stiff joint,



and should these rivets be sheared, there is nothing left to keep the joint stiff.

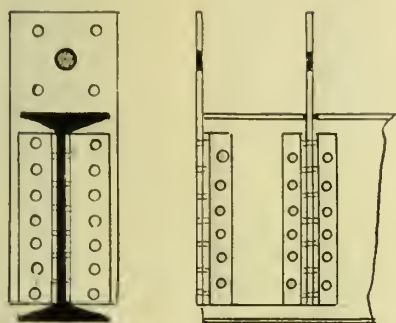


Fig. 18

Fig. 18 shows the connection in which the floor beam is continued through to the outside of the post. It is similar to the preceding connection, except that there can not be any doubt in this case but what the stress is uniformly divided in the post. It has the same objection as the preceding, besides the

objection of having a special hanger plate and having notches cut in the floor beam.

Fig. 19 shows a connection with a diaphragm of four angles and two plates whose duty it is to transfer the stress uniformly to the two hanger plates. The chief objection to this de-

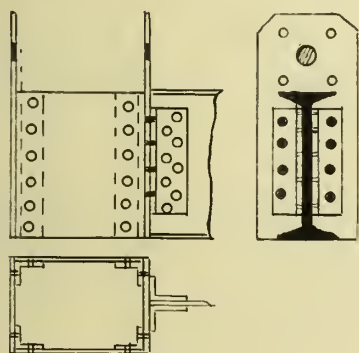


Fig. 19

tail is that the hanger plates do not connect the floor beam to the post so as to form a sufficiently stiff joint. Also a rectangular diaphragm is not as good as one that is I-shaped because it has stiffness about both its axes while it is only needed about one.

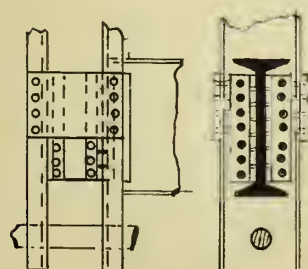


Fig. 20

This floor beam connection in Fig. 20, shows the floor beam attached above the pin. The diaphragm for equally transmitting the stress to the post consists of four angles and a plate in the form of an I. The floor-beam connection shown

in Fig. 21 is closely associated with that of Fig. 20 and both

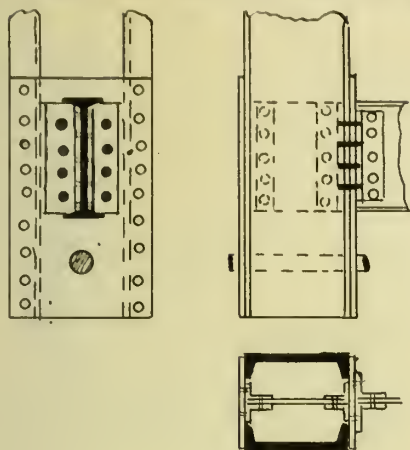


Fig. 21

will be discussed together. This form is different from the preceding in that the connection is made to the pin plate, as the channels have their webs perpendicular to the roadway. Both of these details have as good a diaphragm as possible and both reduce to a small degree, eccentric bearing on the pin and eccentric bearing in the post.

FLOOR JOISTS

The floor joists consist either of wooden beams or of rows of channels and eye-beams. In the latter case, the channels are used on the outside because they carry only one-half of the load. This arrangement also has the advantage of allowing the outside nailing strip to be firmly and easily attached. Wooden



Fig. 22

floor joists are not desirable, because they are uneconomical on account of the facility with which they rot out.

The size of channels and eye-beams should be about seven inches for ordinary highway bridges. The weight of the members and the number of rows are determined by the loading, thickness of floor, and by the panel length. The eye-beams should be bolted to the floor beams by at least two bolts at each end.

In large highway bridges it is the custom to use heavy joists or stringers which are connected directly to the web of

the floor beam. The stringers used in the Homestead and Pittsburgh Highway Bridge are three in number and are built up sections as shown in Fig. 23. These large stringers are built deep so as to increase the section modulus. Here it seems that it is more

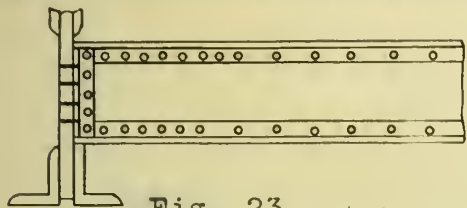


Fig. 23

economical to use the metal thus for increased strength, rather than to use a number of medium sized eye-beams in

order to obtain the same results. Now that large sized eye-beams are more commonly made, it is more economical to use them for stringers instead of the costly built up sections.

JOIST RAISERS

The details for a joist raiser at the roller end will first be considered. One form of joist raiser at the roller end of an ordinary highway bridge consisted, as shown in Fig. 24, of

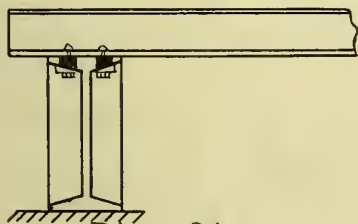


Fig. 24

a single upright eye-beam, that was attached to the roller nest by a slotted plate, and to which the floor joists were bolted with slotted holes. This is

not a good detail for, if the bolts do not slide freely in their slotted holes when the floor joists expand, there is a tendency for the eye-beam to overturn. This would make the sliding of the bolts more difficult and might cause them to be bent, or at least severely strained.

Fig. 25 shows another form inves-

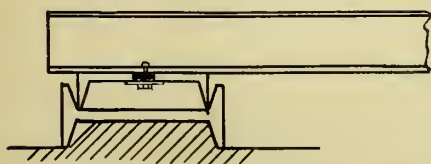


Fig. 25

tigated, consisting of an eye-beam and channel used in the manner illustrated. The eye-beam is attached to the bearing plate with a slotted plate and the floor

joists are bolted to the channel with slotted holes in the latter. The overturning moment referred to above is reduced by this form, but it can be still further reduced and also the bearing on the masonry reduced by the detail shown next.

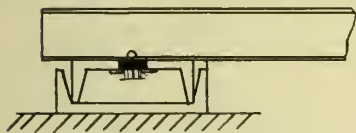


Fig. 26

Fig. 26 shows this detail of joist raiser just referred to. It consists of two channels. The lower channel is bolted to the bearing plate with a slotted plate and the floor joists are bolted to the other channel, which has slotted holes. This detail reduces the overturning moment to practically nothing, and the bearing stress on the masonry is reduced to a very small figure. The detail is simple, efficient, and economical.

The joist raiser at the fixed end will now be considered. Fig. 27 shows the detail for the joist raiser at the fixed end, which was found used in several bridges. It consists as shown

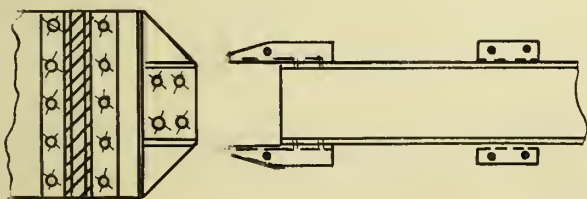


Fig. 27

of a channel with the flanges turned up and angles attached to fasten the floor joists and to attach the joist raiser to the fixed pedestal. This detail would be efficient but the special attachment to the pedestal and the angles required to connect up the floor joists are all an extra expense which can be avoided by using another form.

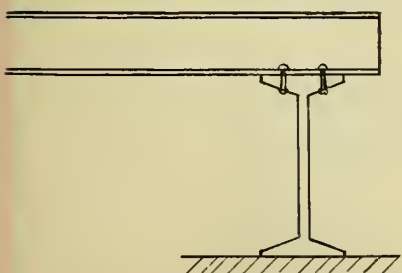


Fig. 28

The common joist raiser used in the ordinary highway bridge consists, as shown in Fig 28, of a single eye-beam firmly attached to the fixed pedestal. The joist raiser at the fixed end need only perform the duty of form-

ing a good support for the floor joists; the overturning moment and stresses at the attachment of the floor joists need not be considered. Fig. 28 shows a joist raiser which gives a good support for the floor joists and which has a bearing stress on the masonry that would come within the safe limits.

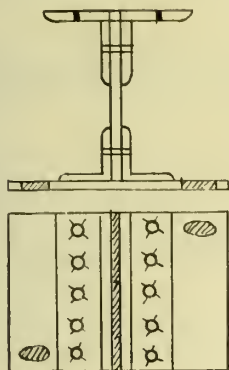


Fig. 29

The construction used to support the stringers of the Homestead and Pittsburgh Highway Bridge are of the form shown in Fig. 29. At the roller end, the bottom plate has slotted holes as shown, while at the fixed end no provision is made for movement.

TOP LATERAL STRUTS

The construction for obtaining rigid connection between the trusses of an ordinary highway bridge, consists of end portals and an upper lateral system of which the top lateral struts are a part. These bridges being of short span, are shallow and

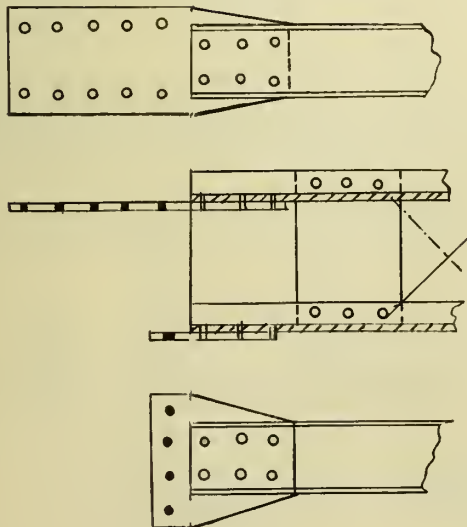


Fig. 30

sufficient stiffness is obtained by the above construction as the upper lateral system transfers the wind stresses to the ends of the upper chord, which in turn, transfer them to the abutments.

One form of strut found among the bridges investigated consists, as shown in Fig. 30, of two channels laced together. The flanges of both channels are turned up. If the top

channel were extended over the top chord and riveted directly to it, a stiffer connection would be made. It would be advantageous to turn the flange of the lower channel down, for then the channel would not be a collector of water and could be directly riveted to the top chord.

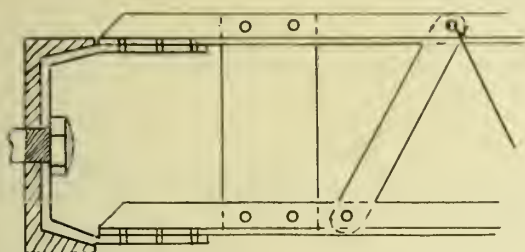


Fig. 31

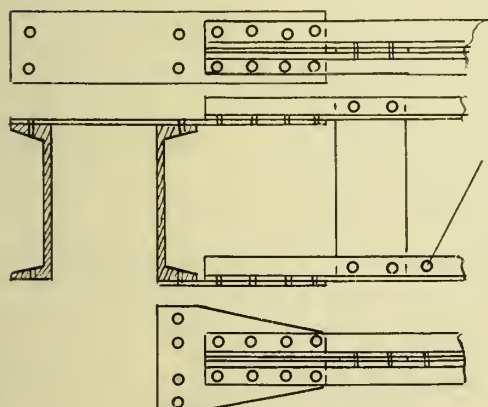


Fig. 32

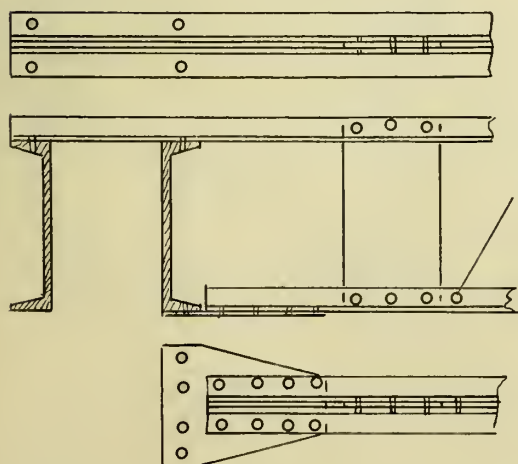


Fig. 33

The form of strut shown in Fig. 31 was found commonly used in ordinary highway bridges. It consists of two pairs of angles placed back to back and connected by lacing.

This form is better than the use of two channels for the following reasons: it is more economical, for its construction requires half the lacing, and therefore, half the riveting required for the other form; the legs of the angles corresponding to the web of the channel are as efficient in giving stiffness as the latter; the legs of the angles corresponding to the flanges of the channel are heavier than the light flanges and are therefore stiffer.

In most of the details investigated, the legs were turned up. No especial advantage is obtained by this except where the top angle is extended over the top chord and riveted directly to it as in Fig. 33.

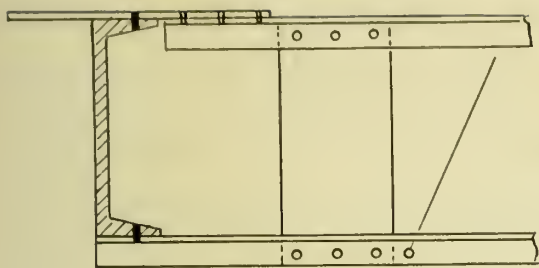


Fig. 34

It would therefore be better to turn the legs down as in Fig. 34, for they would not then be subject to collecting dirt and water.

The connection shown in Fig. 31 consists of a bent plate fastened to the top chord by the pin nut. This detail affords easy erection, but

should be condemned because of the expense of constructing the bent plate and because of the utter lack of rigidity of the connection.

The connection shown in Fig. 32 is efficient and simple, but if the strut was constructed with the leg of the top angles up, a much more rigid connection would be made by extending the angle over the top chord as shown in Fig. 33.

The connection of the strut shown in Fig. 34, affords a stiff and efficient connection. The batten plate at the end should be connected to the angles by at least three rivets in order to avoid bending at the ends and causing secondary stresses to be brought upon the rivets of the connection.

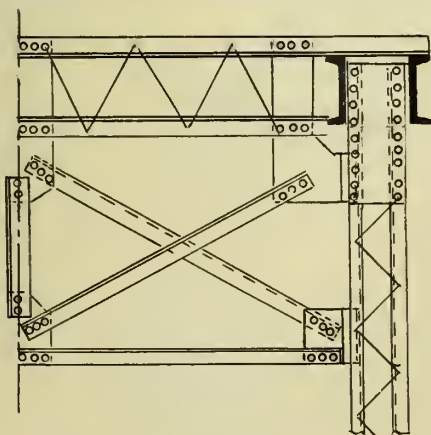


Fig. 35

In highway bridges of long span the trusses are deep and it is necessary to use some system of sway bracing more efficient than the ordinary strut in order to make a more rigid connection between the trusses.

Fig. 35 shows the sway bracing used in a 197-foot span highway bridge. The

top lateral strut is composed of two pairs of angles linked to-

gether. The top angles are riveted directly to the top chord, thus making a stiff connection. The diagonal members of the sway bracing consist as shown, of single angles with the legs turned down, the advantage of which has been previously discussed. These angles are designed to take either compression or tension. The connections are made as shown by means of plates and angles. The object of securely riveting the diagonal angles at their intersection is to lessen the unsupported distance of these angles and thus enable a smaller section to be used in the compression members.

DIFFERENT TYPES OF PORTALS

The different types of portals for the ordinary highway bridge will be first considered. Although the portals transfer stresses of considerable magnitude to the end posts, and these stresses would theoretically be best transferred centrally to the posts, this ideal connection is impracticable for ordinary highway bridges for the following reasons. Practice has proved the con-

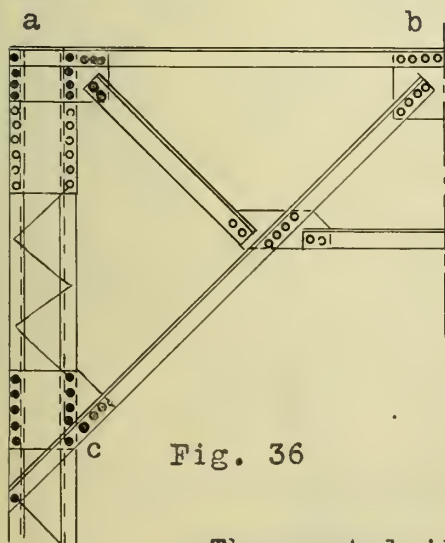


Fig. 36

nections to the top of the end posts effective; ordinary connections to the sides of the posts subject the rivets of the connection to tensile stresses; and it would be unwise to substitute expensive ideal connections for those which practically satisfy the conditions.

The portal illustrated in Fig. 36, is a very common type, and is a very simple and effective detail. The members A-B and B-C take the stress and the other members are inserted to

stiffen B-C and to decrease its unsupported distance. The connecting plates are field riveted to the top of the posts as shown. This is a good detail as connecting plates like these, should never be shop riveted to a heavy member because they are liable to be bent in transportation. A-B and B-C should be designed to resist both tension and compression (see Johnson Framed Structures, p. 320).

In the form of portal illustrated in Fig. 36, the unsupported distance from the lower end of the end post to the connection of C-B is shorter than in most of the other types of portals. This is a strong point in its favor, as the above connection decreases the bending moment in the post, and accordingly the secondary stresses due to the bending moment. These secondary stresses often seriously damage the rivets and connection plates.

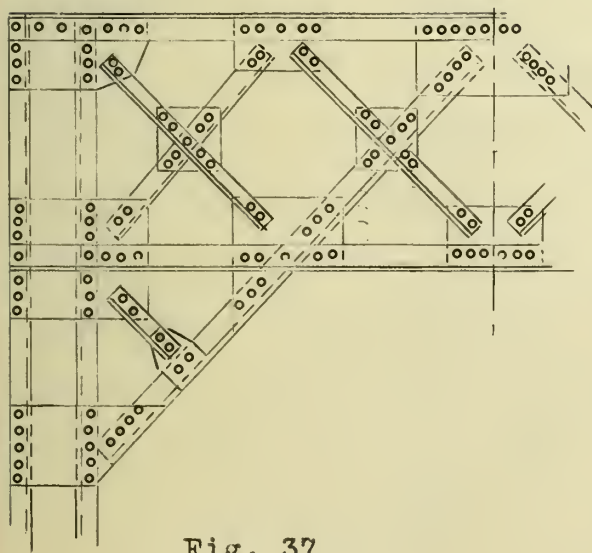


Fig. 37

Fig. 37 also shows a form of portal that is commonly used. It is sometimes used without the knee brace, but it should not be, as the knee brace reduces the bending moment in the post. The angles are used here with their legs up. There is no advantage in this; and the legs should be turned down in order that dirt and water may not collect

in the angles. Another objection to this detail is that the connecting plates are shop riveted to the end post. This portal is more rigid than the preceding, and is also better from an aesthetic point of view.

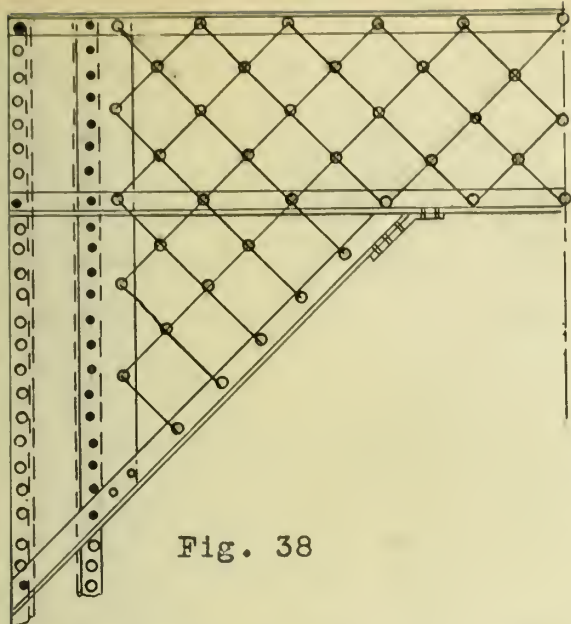


Fig. 38

The type of portal shown in Fig. 38 was also used on several of the bridges investigated. It is sometimes used without the knee brace, and this has the same objection as given above. The connection of the knee brace to the strut is objectionable because the connecting rivets will be subject to tension.

The portal is very rigid because of its lattice construction and because it is very firmly attached to the end posts.

Several long span highway bridges that were investigated had types of portals and connections as have been described. Since the portal connections are subject to severe reverse stresses, and the portal stresses of such bridges are very large, there has been, of late years, a tendency to design the portal and connections so as to transfer this stress as centrally as possible to the end posts. The portals are therefore constructed as a box girder, with the webs in the planes of the top plates and of the under sides of the end posts. The connecting plates extend across the entire width of the end posts in both planes. This avoids direct tension on rivets and is as nearly central as it is possible to make the connections.

TOP LATERAL DIAGONALS AND CONNECTIONS

The top lateral systems of the ordinary highway bridges investigated, consisted mostly of rods designed to resist tension only. Sometimes, but rarely, it consisted of angles which were de-

signed to resist both tension and compression. The latter detail is better as it makes the bridge stiffer but it is questionable, for ordinary highway bridges, whether the extra rigidity gained will more than offset the increase in cost that is necessary. When designed to resist only tension, the system consists simply of single rods or bars which are made adjustable by nuts screwed on their threaded ends and by which they can be tightened up to the requisite amount of initial tension.

The top lateral diagonals of the large highway bridges consisted in general of angles although the use of rods was noticed in several instances. The use of rods is poor practice in this case where stiffness is such an essential requirement. In the cases noted where angles were used, the diagonals consisted of single angles. The diagonals are connected by a plate at their intersection and are riveted directly to the cover plate of the top chord. Thus a rigidly connected cross frame is formed in each panel, which besides performing the duty of transferring the wind stresses to the end portals, also serves to help in stiffening the bridge.

Since the use of rods is almost universal for ordinary highway bridges and has proved efficient in practice, the connections of the rods to the trusses will now be considered.

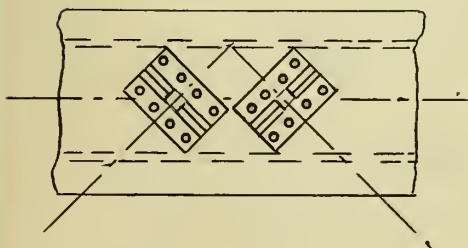


Fig. 39

Fig. 39 shows a top lateral connection consisting of two angles placed back to back. The rods and angles are at right angles to each other. This detail is objectionable as tensile stresses, caused by the overturning moment, are produced in the rivets in the angles.

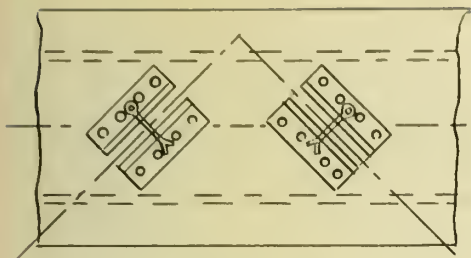


Fig. 40

The detail shown in Fig. 40, has the angles parallel with the rods. This method of connection makes the overturning moment unappreciable. A small cotter pin prevents the rod from becoming displaced. This connection is to be recommended because it is efficient, simple, and economical.

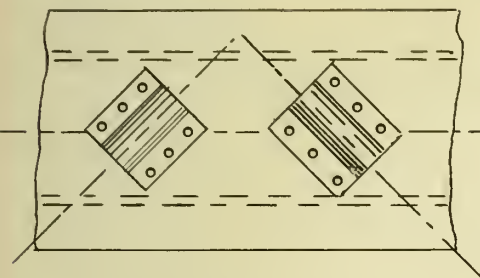


Fig. 41 preceding in that a cotter pin is not required. The chief objection to this detail is the uneconomical shop expense attached to bending it into its peculiar form.

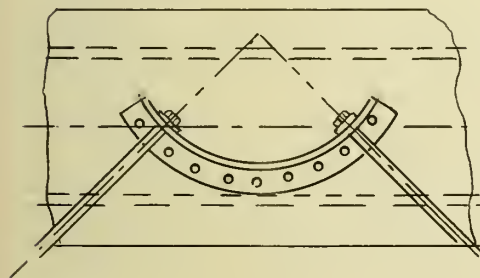


Fig. 42

Fig. 42 shows the standard detail of top lateral connection used by the Massillon Bridge Company. It consists of an angle bent in a semi-circle as shown. This connection distributes the stress over a large area of the cover plate but it is liable to some overturning moment. Also the shop cost of bending an angle into this form makes the detail uneconomical.

BOTTOM LATERAL DIAGONALS AND CONNECTIONS

The objection to using angles for the bottom lateral system of ordinary highway bridges, is the same as that stated in

the case of the upper laterals. Rods adjusted by nuts screwed on their threaded ends, can be used with good results. Loop bars, adjustable by turn buckles, are sometimes used. The principal objection to these is the cost of welding the looped ends and the cost of the turn buckles. A good form of bottom lateral rod is looped at one end and has the adjusting nut at its threaded end. It can be easily adjusted, and a simple and efficient connection can be used.

Highway bridges of long span have angles for the bottom lateral system because of the additional rigidity obtained by their use. The angles are riveted directly to the ends of the floor beams and are connected where they intersect, by a plate. This connection stiffens the angles and decreases their unsupported lengths. In one large bridge, the diagonals were made up of two angles riveted back-to-back. These diagonals were connected at their ends to the floor beams, by plates riveted to the floor beams and the bottoms of the end posts. Connections were made between the diagonals and also to the stringers. In addition to this, a small transverse angle attached to the stringers also stiffens the diagonals. These details make a very rigid system of connection

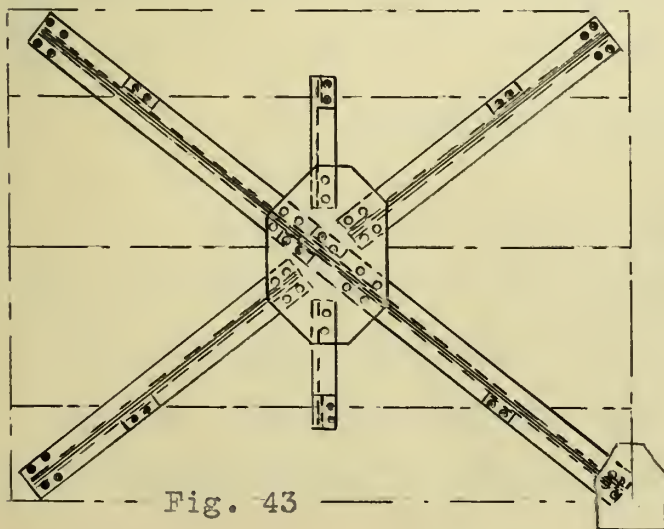


Fig. 43

between the trusses besides performing their duty of taking care of the wind stresses. Fig. 43 shows the arrangement of this connection.

The lateral connections for the ordinary highway bridges are made directly to the floor beams which also act

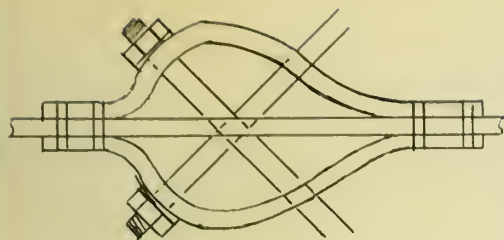


Fig. 44

cost of their construction.

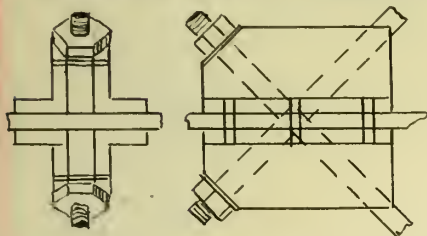


Fig. 45

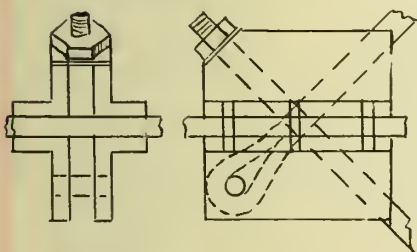


Fig. 46

as struts. The connection shown in Fig. 44, is used where rods, adjustable by nuts at both ends, are employed. An objection to this detail is the disadvantage of using bent plates because of the

A lateral connection, used under similar conditions to the preceding, consists as shown in Fig. 45, of four angles. It affords a good stiff connection, and is an efficient and economical detail.

The connection shown in Fig. 46, is one that is used with rods looped at one end and having the adjusting nut at the other end. This connection is identical to the preceding except for the difference in the laterals. It will be

noticed that all these connections require a hole to be cut in the web of the floor beam. This is done to prevent the rivets of the connections from being subjected to tension.

DIFFERENT TYPES OF PEDESTALS

The pedestals of a bridge perform the duty of transferring the entire stress of the bridge, due to its weight in loading, to the abutments. The pedestals should transfer this stress uniformly over the masonry plates and hence it is very important that their details should be designed with this end in view.

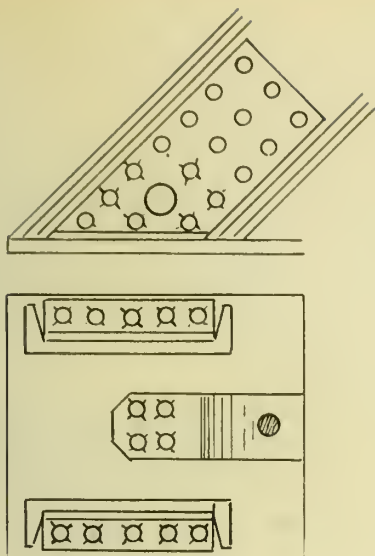


Fig. 47

The pedestal shown in Fig. 47, consists of a shoe plate riveted to the end post by bent plates. This is a very objectionable detail because any movement of the end post due to deflection under loads or due to expansion, would tilt the pedestal on one edge and cause stresses upon the rollers and bed plates far above the allowable limit. Also the stresses of the end post would not be transferred to the pedestal by the pin as they should be, and when the pedestal is tilted up the stress is brought upon one edge of the end post, causing serious eccentric stresses. Still another objection, is the uneconomical shop cost of constructing the bent plates.

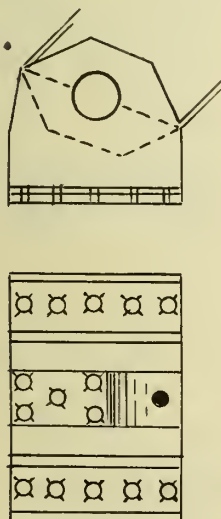


Fig. 48

Fig. 48 shows a pedestal consisting of two bent bolster plates riveted to the shoe plate. The pedestal is pin-connected to the end post thus avoiding eccentric stresses in the latter, and distributing the stress uniformly over the bearing area of the pedestal. The bent bolster plates are objectionable,

firstly, because of the shop expense of constructing them, and secondly, because the plates are not rigid enough to make them stable against the lateral pressure of the wind.

The pedestal shown in Fig. 49, is identical to the pre-

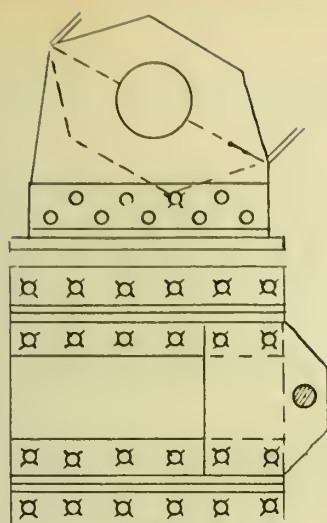


Fig. 49

ceding except that the bolster plates have stiffening angles. It is well to have the stiffening angles connected to the bolster plates by two rows of rivets, because single riveting would not give a connection efficient in regard to stiffness. The stiffening angles also transmit part of the stress to the shoe plate, thus distributing the stress more evenly. The bent bolster plates are objectionable because of their extra shop expense.

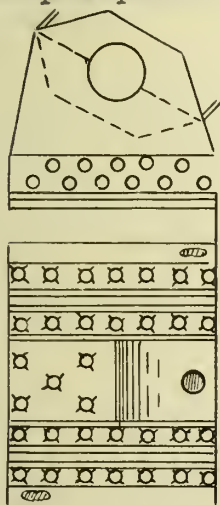


Fig. 50

Fig. 50 shows a form of pedestal that was found to be very generally used. It consists of bolster plates riveted to the shoe plate by two angles. Thus the bolster plates are held very rigid. The additional strength and rigidity, obtained by two rows of rivets connecting the angles and bolster plates, is of great advantage. This pedestal, because of its strength and rigidity, is very efficient for ordinary highway bridges.

For highway bridges of long span the pins are larger and longer and therefore have to be supported at intermediate points in order to decrease their bending moment. A pedestal used on a 370-foot span of the Homestead and Pittsburg bridge is given in Fig. 51. It will be noticed that no stiffening angles are used in this detail. They could not be used; firstly, because they

would not give clearance for the connection of the end post and

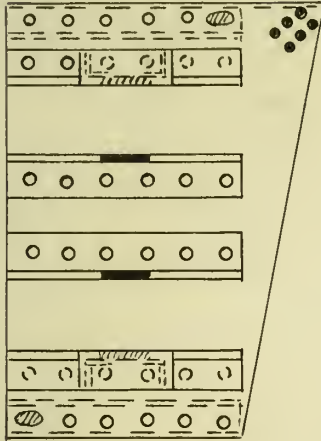
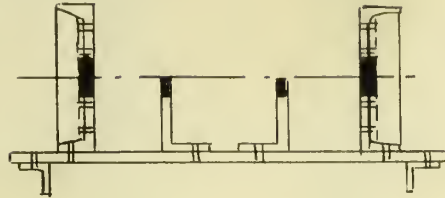
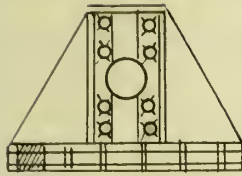


Fig. 51

lower chord; secondly, because the pin sets so close to the shoe plate that the overturning moment of the lateral wind pressure would be small; and thirdly, because the direct stress from the end post is so large that the lateral pressure of the wind has little effect on the pedestal. The end supports of the pin are made of channels stiffened by vertical angles. The use of this detail which had no alternative but a bent plate is to be recommended.

ROLLERS AND PLATES

All spans under 75 feet usually rest on planed bed plates and expand or contract by sliding on the surface between the sole and bed plate. Spans over 75 feet should be provided with rollers. Without some such device for decreasing the friction, the continual expansion and contraction of the trusses produced by changes of temperature, would tend to destroy the masonry. Rollers are only used at one end of the bridge, the other end being firmly fixed to the masonry.

Fig. 52 shows a roller nest that is attached directly to the masonry bed plate. The angles on the side hold the rollers in place and also project a little above the rollers and keep the

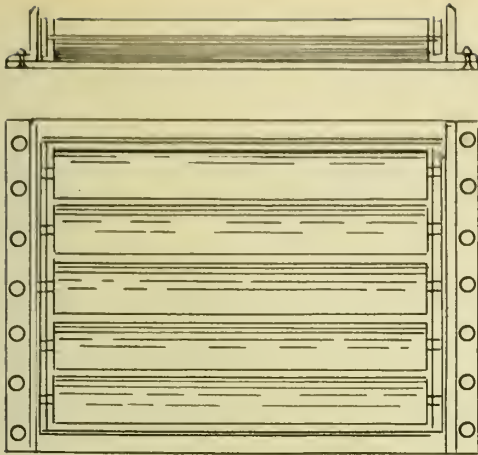


Fig. 52

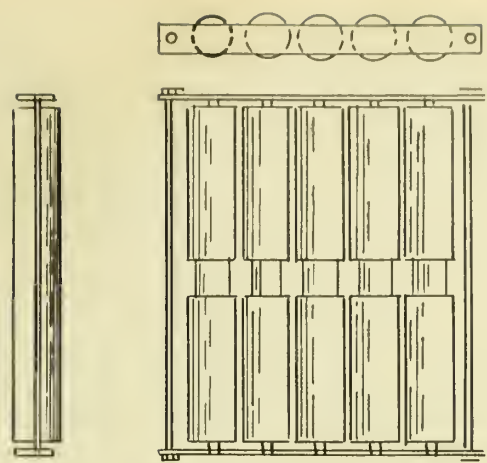


Fig. 53

pedestal from slipping to either side.

The rollers shown in Fig. 53, constitute practically, the only alternative form of the preceding. The rollers are held in position by two side bars which are fastened together by rods as shown. The masonry bed plate and the shoe plate of the pedestal have narrow plates attached to their bearing surfaces and these plates fit into the grooves shown in the rollers. This is a very efficient detail for keeping the pedestal and roller nest in place.

The size and number of rollers used in a nest depends entirely upon the amount of stress and the area of the shoe plate. In ordinary highway bridges five rollers to a nest were found ordinarily used. The rollers for highway bridges should always be at least four inches in diameter. If smaller rollers are used, the nest is liable to be clogged up with rust and become useless. The spacing between rollers should be $1/4$ of an inch.

The roller diameters of many of the bridges investigated were from $1\frac{3}{4}$ inches to $2\frac{1}{2}$ inches. The rusted and clogged $2\frac{1}{2}$ -inch rollers of the highway bridge at St. Joseph, Illinois, is an example of the non-efficiency of such rollers.

MINOR DETAILS

(a) METHOD OF FASTENING FLOORS

Where wooden floors are used on highway bridges it is very important that they should be securely fastened for they are subject to severe jolts and strains. If not securely fastened, the bearing surfaces of the boards will be more liable to be crushed and chafed.

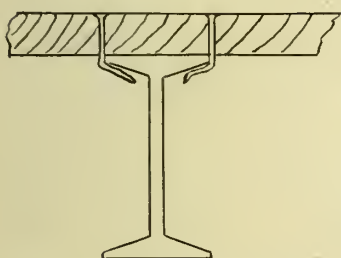


Fig. 54

Fig. 54 shows a method of fastening the floor without the use of nailing strips. Nails driven into the floor are clinched around the floor joists as shown. It is plainly apparent that this forms a loose unstable connection.

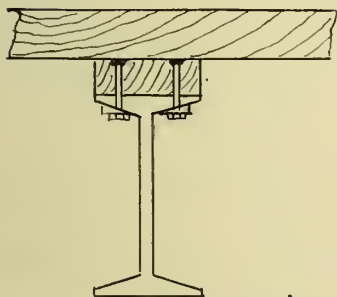


Fig. 55

Another connection, as illustrated in Fig. 55, is accomplished by nailing the floor to nailing strips bolted to the top of the floor joists. This connection makes it necessary to use a nailing strip on each floor joist and this is not necessary and is therefore uneconomical. This detail is also ob-

jectionable because the nailing strips could not be replaced without tearing up the entire floor.

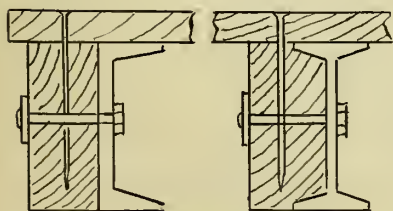


Fig. 56

The method of fastening floors as shown in Fig. 56, was found very commonly used. Nailing strips are bolted to the outside channels and to one or two of the intermediate floor joists. The nailing strips can be

easily replaced if necessary. They afford an efficient connection and are economical as only three or four nailing strips need be used.

(b) WOODEN FLOORS

The use of wooden floors for highway bridges is almost universal, and it is only of late years that they have been supplanted to some degree by concrete floors.

One common form of wooden floor consists of a sub-floor of planks laid diagonally across the floor joists and a top or wearing floor made of a better wearing wood. The latter floor consists of planks laid transverse to the roadway. This form of floor is used to keep material from dropping through the floor and should have felloe guards along the side to keep the material from going over the edges. This type of floor, being built so tightly, is not well drained or ventilated, and is on that account liable to rot out quickly.

Another type of wooden floor more adapted to country use than the preceding consists of one layer of heavy plank laid transverse to the roadway. The plank should be at least 2 1/2 inches thick and 8 inches wide and spaced apart 1/4 of an inch. This will give a floor that is well drained and ventilated and will, on that account, be longer lived than the preceding floor.

A type of floor commonly used in cities consists of a layer of boards laid diagonally across the floor joists and a wearing surface or pavement of wooden blocks laid on top. These floors become saturated with water, and, having very little chance of drying out, rot out quickly, unless the wooden blocks are treated

with a preservative.

(c) CONCRETE FLOORS

The use of concrete and masonry floors for highway bridges is now becoming quite common. Fig. 57 shows a very excellent floor. It is made with brick arches sprung between the



Fig. 57

floor joists, and filled in above with cement. The cement is covered with a coating of asphalt and a Macadam pavement is placed on top.

This floor would be in most cases entirely out of consideration because of its excessive cost and also because it would greatly increase the dead load (see Engineering London Jan. 24, 1896).

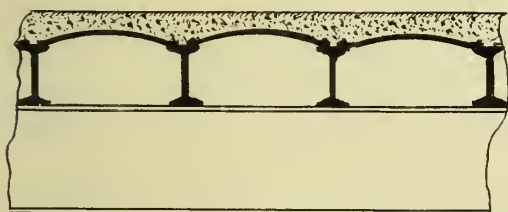


Fig. 58

The floor system shown in Fig. 58 consists of arch buckle plates riveted to the tops of the floor joists. They support a layer of concrete that is $2\frac{1}{2}$ inches thick at the crown of the buckle plates. A pavement of asphalt $1\frac{1}{2}$ inches thick completes the bridge floor (see Engineering Record Nov. 11, 1899).

A pavement of asphalt $1\frac{1}{2}$ inches thick completes the bridge floor (see Engineering Record Nov. 11, 1899).



Fig. 59

The bridge floor shown in Fig. 59 consists of concrete arches sprung between the floor stringers. The stringers are spaced about five feet apart and are tied together at intervals of five feet, by $\frac{3}{4}$ -inch rods. The concrete arches were covered with a layer of sand and

a brick pavement laid on top. This form of floor cost less than one-half as much as the buckle-plate floor (see Engineering News Mar. 10, 1898).

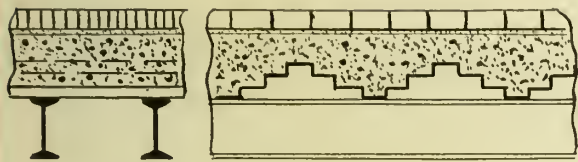


Fig. 60

Fig. 60 shows a bridge floor used on the Eighth Street bridge of Allentown, Pennsylvania. Sheet iron, bent in the form shown, is laid across the floor stringers and concrete laid on the top of this

surface. A pavement of asphalt, 1 1/2 inches thick, forms the wearing surface of the floor. This use of sheet iron support for the concrete has been found more economical than the use of buckle plates.

(d) SIDEWALK SUPPORTS

Fig. 61 shows the type of sidewalk support that is commonly used. It consists of a continuation of the floor beam.

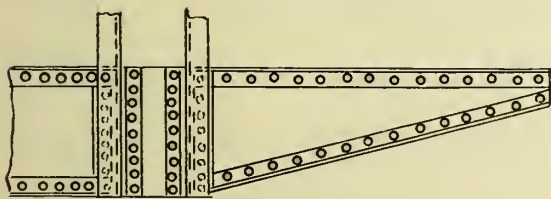


Fig. 61

This type of support has all the rivets of the post connection in tension, and is objectionable on that account.

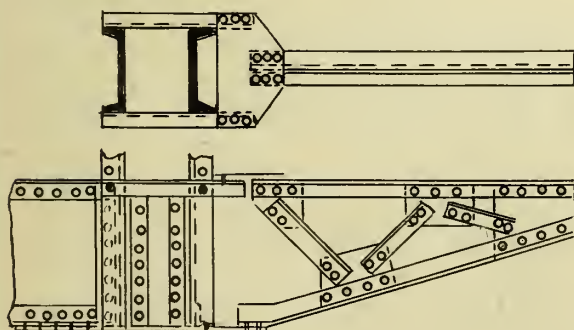


Fig. 62

Fig. 62 shows a sidewalk support of good detail. It is somewhat more difficult and more expensive to make connections which will not have their rivets subjected to tension, but a much more efficient support is obtained. In the

sidewalk support of Fig. 62, the connection of the top angles is

made to a plate which is connected to two angles field riveted to the sides of the post. The bottom angles are connected to a plate which is field riveted to the bottom of the post and floor beam.

SUMMARY OF THE BEST DETAILS

The various details have been investigated and discussed and a summary of the details as should be used as standards for the ordinary highway bridge will now be advised. These recommendations must be understood to refer to the ordinary pin-connected Pratt-truss highway bridges of spans of from 75 to 175 feet. The author does not deem it advisable to set certain standards details for large highway bridges as the different types of trusses, different loadings, and various other conditions make this almost impossible. Going to the other extreme, practically the same conditions hold true for the small, riveted, pony-truss spans.

End Posts and Upper Chord.- The detail for end posts and upper chord shown in Fig. 1, is advisable except that the cross sections shown in Fig. 2 should be used if the required area is great enough to allow it to be done. The same cross sections should be used throughout the end post and upper chord, and the use of the cover plate should be avoided when possible. Either single or double lacing may be used but the latter is recommended. batten-plates should not be less than $1\frac{1}{2}$ the least width of the member and must always be at least $\frac{5}{16}$ of an inch thick. The thickness of the thin plates is determined by design, but the longest pin-plate should be made to extend about six inches beyond the batten-plate.

Intermediate Posts.- The intermediate posts should consist of two channels connected by lacing as shown in Fig. 4. The flanges of the channels should be turned out and the webs should be perpendicular to the roadway. The connection to the top chord should be made as shown in Fig. 7. Single lacing should be used. Batten-plates should not be less than $1\frac{1}{2}$ times the least width of the member.

Hip-Verticals.- Sketch (a) of Fig. 11 is to recommended as the standard form of hip-vertical. Eye-bars should be used in preference to loop-bars.

Floor-Beam Connections.- The best details of floor-beam connections and the ones advisable for use are those shown in Figs. 20 and 21. The connection angles should always be shop riveted to the floor-beams and field riveted to the posts.

Floor Joists.- The system of channels and eye-beams shown in Fig. 22 is recommended as the best detail for floor joists. The size of the channels and eye-beams should be about 7 inches, and each joist should be bolted to the floor-beam by at least two bolts.

Joist-Raisers.- Two channels used as shown in Fig. 26, constitute the best form for use at the roller end of the span. A single eye-beam used as shown in Fig. 28, is recommended as good form for use at the fixed end of the span.

Top Lateral Struts.- Angles laced together as illustrated in Fig. 34, form the best detail for the top lateral strut. The connection to the top chords should be made as shown in Fig. 34. The stiffening plates at the end of the strut should be riveted to the angles by at least three rivets.

Portals.- The portal shown in Fig. 36, is recommended as an economical and efficient detail. The type of portals shown in Fig. 37 is also recommended and it is a better one than the preceding, when considered from an aesthetic point of view. The plate connections to the end post should be field riveted as in Fig. 36. Also, all angles should be placed with their legs arranged as there shown.

Top Lateral Diagonals and Connections.- The recommended form of top lateral diagonal is that of single rods made adjustable by nuts screwed on their threaded ends. The best form of top lateral connection is shown in Fig. 40.

Bottom Lateral Diagonals and Connections.- Two forms of bottom lateral diagonals will be recommended. One form consists of a single rod made adjustable by nuts screwed on its threaded ends. Fig. 45 shows the connection for this form. The second form consists of a single rod looped at one end and having an adjusting nut on the other end. Fig. 46 shows the connection for this second form.

Pedestals.- The pedestal illustrated in Fig. 50, is recommended as a good detail. Each post or plate should be riveted to the shoe plate by two stiffening angles. These stiffening angles should be riveted to the bolster plate by two rows of rivets.

Rollers.- The best form of roller nest is shown in Fig. 53. Rollers should always be at least four inches in diameter and spaced $1\frac{1}{4}$ inch apart.

Method of Fastening Floors.- Fig. 56 shows the recommended method of attaching wooden floors. The nailing strips must be securely bolted to the floor joists and should be at least three in number.

Kind of Floor.- A wooden floor is recommended for the common country highway bridge. Such a floor should consist of at least 2 1/2-inch plank 8 inches wide. This should be laid transverse to the roadway and spaced 1/4 inch apart. Where concrete floors are used, such as on city or park highway bridges, any of the forms shown in Figs. 58, 59 and 60 are advisable. The floors shown in Fig. 59 and 60 are the most economical.

Sidewalk Support.- Fig. 62 illustrates a sidewalk support that is recommended as a good detail.

CONCLUSION

The sections of the main members and the details discussed and illustrated in this thesis, were picked out as representative examples in common use among the ordinary highway bridges. Their various defects and merits have been discussed and a very small minority of those investigated were without serious faults. The preceding summary gives the most efficient and economical sections and details which were investigated. Although the author does not claim that these recommended sections and details have not equally good alternatives, he does claim that they can be relied upon as being efficient, and economical in respect to design, construction and erection.





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